The WHAT'S NEW magazine

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STEALTH!

Finally, it's official: The B2 bomber exists. It will fly this fall. Here's what the Air Force revealed and what it didn't

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Popular Science

What's News

Finally: Stealth!

So we're finally going to get a look at a real stealth airplane. We're pleased that it will look pretty much the way we showed it on our September 1986 cover. We've dug up a good many new details on the B-2, as you will find in the piece starting on the next page.

Video ball and chain

In March POPULAR SCIENCE's cover showed the Mitsubishi VisiTel—a new low-cost videophone that transmits pictures on ordinary phone lines. So I was fascinated recently to spot the same piece of equipment in a photograph in *The New York Times*, especially because the accompanying piece was about keeping jail crowding down in Anne Arundel County, Md. It told of a man who had been convicted of drunk driving for a third time. He was sentenced to two months of nighttime house arrest and was also told not to drink. How do authorities make sure he is at home—and sober? Twice nightly, at random times, they call him on the videophone. He answers with his VisiTel. Not only can authorities see that he's home, they can also watch as he uses a hand-held breath analyzer, which displays blood-alcohol levels in bright red numerals that can be read over the VisiTel. So far seven people under house arrest in the county have been issued the units. For the county it's cheaper than keeping someone in jail. And the customers are reasonably happy. One unidentified user complained that he was sometimes awakened at night by the call from the county. "I'm not happy about it," he said, "but it sure beats going to jail."

Pedal-powered plunge

The *Da Vinci II* finally got off the ground—maybe. The pedal-powered helicopter built by students at California Polytechnic State University [May] quivered briefly as pilot Andres Eulate pedaled furiously and may—just may—have lost contact with Earth briefly. Nobody is sure. Then bicycle racer Ted Ito, fresh and burning to make history, climbed into the pilot's seat. A few minutes later the 140-foot rotor blade lay on the floor, smashed beyond repair.

Scott Larwood, student director of the project, says the problem was that Ito weighs 15 pounds less than Eulate. That apparently changed the helicopter's balance, so it pitched forward when ground-crew members let go. Now the team is evaluating whether to rebuild the single wing or change the design to a three-bladed rotor.

Energy roundup

- More news on the coal front: A decade ago, a way of burning coal called fluidized-bed combustion received considerable attention, most recently in this magazine in December 1981 ["Multi-fuel Combustor"]. In such a system coal and crushed limestone are mixed, then fed to a furnace in which they burn while suspended in a churning mass on a column of air. As the coal burns, the limestone absorbs the sulfur dioxide it produces, ending or reducing the need for costly wet scrubbers. Now two major fluidized-bed plants have come on line—a 110-megawatt plant at Colorado Ute Electric Association's Nucla station and a 130-megawatt installation at Northern State Power's Black Dog plant. The technology could later be useful in reducing acid rain and other air pollution.
- The British have put another $15 million into a long-range project to develop dry-hot-rock geothermal power. Engineers are investigating a site in Cornwall and hope to start building a plant in 1991 when preliminary engineering work has been completed. They calculate that the site contains enough heat to generate between 750 and 3,000 terawatt-hours of energy, enough to supply power to southwest England for the foreseeable future.

Better oil

The Society of Automotive Engineers has recommended that car owners start using a new type of engine oils, labeled SG. The new oils have been compounded to reduce engine wear. SG oils should improve performance and durability of car engines, the SAE says. They will soon be available, and you can tell when you're buying the new lubricant by checking the doughnut-shaped symbol on the can. What's different about SG oils? Tom McDonnell, chairman of the SAE fuels and lubricants division, says SG oils have significantly more dispersants, detergents, oxidation inhibitors, and anti-wear agents.

An Audi 12-banger?

BMW has one [Feb.]; Daimler-Benz is developing one, as is Cadillac. Now the (unofficial) word is that Audi will have a 5.3-liter V12, or maybe a V10, in a limited edition, four-wheel-drive, active-suspension, high-priced super coupe. Audi won't confirm the rumor.

Metric again?

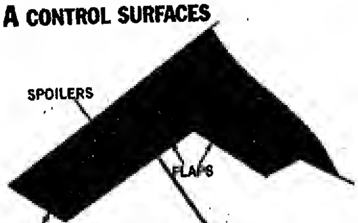
The count is down. Now only Burma and the United States still use English measure. Even England has scrapped this system. You may remember that the Metric Conversion Act of 1975 set up the goal of slow conversion in the United States, and envisioned a slow fading away of feet, pounds, and quarts. What faded instead was the act.

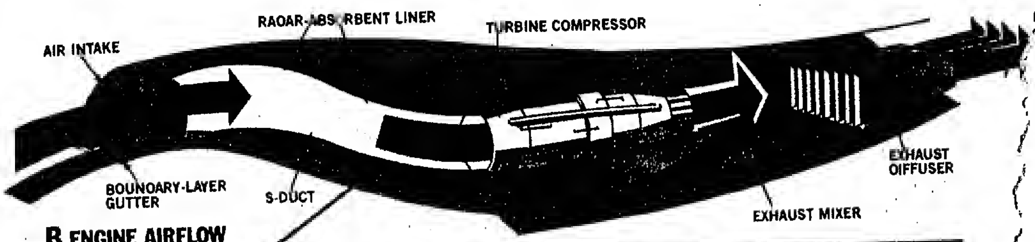
Now the Defense Department is going to give metric another nudge. Anyone bidding on a defense contract must now use metric specifications. The reason: simple economics, says the Department. The move will end NATO's expensive dual inventory system and make it easier for foreign companies to get involved in joint development programs. One Pentagon official recalling the distinct lack of enthusiasm with which the country received the general metrification attempt in the mid-70s quipped, "We're not trying to change the way people live—just the way they fight."

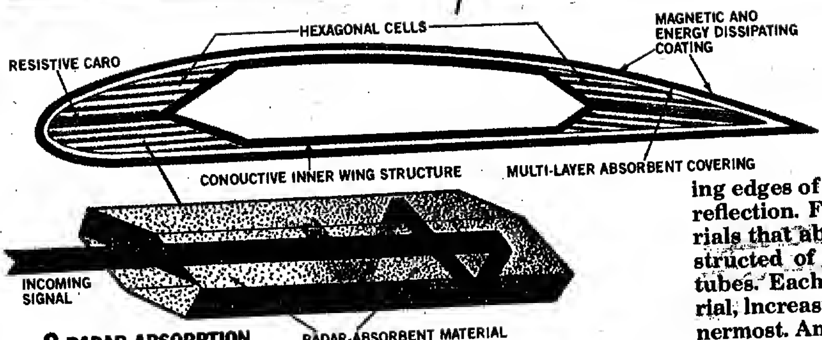
C.P. Gilmore

Editor-in-Chief

What the Air Force isn't saying—critical elements not shown







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The official painting of the B-2 released by the Air Force (above) shows a boomerang-shaped structure with a saw-tooth trailing edge and three raised pods on the wing. Two are obviously for engines, the third is for crew and probably weapons. No control surfaces are shown. Experts guess that in the absence of any vertical stabilizer, directional control (A) might be achieved with elevons on the wingtips. Spoilers raised on one wing and not the other might introduce drag on one side, thus initiating a turn. Flaps might be mounted in the most forward parts of the serrated trailing edge, because that would put them closest to the center of gravity, where they would have minimum effect on pitch. Engine mounting is critical (B). Air probably flows through the intakes on top of the wing through an S-duct to the engines. Thus the engine compressor—a strong potential source of radar echoes—is hidden from incoming radar signals. A vaned diffuser flattens the exhaust jet into a thin, wide plume, making it harder to spot by satellite-borne heat sensors. A thin additional inlet called a boundary-layer gutter can be seen below each main inlet. These probably serve two purposes. First, a layer of turbulent air near the top surface of the wing can be bled off through this inlet, smoothing the flow into the engine. Second, the additional air is mixed with the jet exhaust, helping to cool it, further reducing the chance of IR detection. The leading and trailing edges of the wing (C) are constructed to minimize radar reflection. First, they are covered with multilayered materials that absorb radar signals. Second, the edges are constructed of a series of thumb-size hexagonal honeycomb tubes. Each hexagon is filled with radar-absorbing material, increasing in density from the outermost edge to the innermost. An incoming radar signal first strikes and is partly absorbed by the multilayered covering. The rest goes into a hexagonal cell. As it penetrates, it continues to be progressively absorbed. The remaining signal that strikes the angled surface at the rear is reflected in a zigzag pattern back through the cell, continuing to be absorbed along this even longer path. Such a technique might nearly eliminate radar reflection from the wing edges. "It's a Roach Motel for radar waves," said one observer. "They check in, but they don't check out." Although it is not shown in the official Air Force version, some experts think the wing-top pods will be faceted rather than smoothly contoured (D). When a radar signal strikes a normal contoured surface of the kind found on most aircraft, a glint is transmitted back in almost any direction, making the target easy to see on radar. A faceted surface, on the other hand, tends to reflect signals in directions slightly different from the direction from which they came, so they do not return to the originating radar. The surface, of course, would also be coated with radar-absorbent material to reduce reflections in any direction. One possible countermeasure that might be applied against a stealth aircraft is bistatic radar, in which the transmitter is at one location and the receiver at another (E). The signal transmitted by either ground or satellite transmitter can ricochet off the target and be received by a separate ground receiver. Another advantage of this arrangement: The listening ground station is passive; because it is radar-silent, its location cannot be determined by the attacking plane.

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frog the next generation of manned bombers directly into the world of stealth. The Reagan administration later reinstated a revised B-1 program, now the B-1B. The B-1B, now going into operation, is scheduled to serve as a bridge to the time when the B-2 will be brought into operation—the 1990s.

Engineering secrets of the plane radar can't see

A daunting task—building an airliner-size flying structure that even super-sensitive military radars can't find. First job: reduce what engineers call the RCS—radar cross section. The smaller the RCS, the smaller the echo returned from a radar signal of a given signal strength. A clue as to how this might be done appeared shortly after World War II, when radar had changed the rules of the military game. Engineers noticed that some planes returned far larger radar images than others of essentially the same size. "The problem is that an aircraft, or parts of it, can act like an antenna, reradiating radar signals that strike it," said M. William Frasca, an expert in radar-absorbent materials.

Some planes were better natural reradiators than others. In particular, experts pointed to the Russian TU-95 Bear and the British Vulcan bomber. The TU-95, with huge eight-bladed propellers, a tall vertical stabilizer, and many sharp angles, returned a massive radar echo. The Vulcan, by contrast, was a wedge-shape flying wing with the engines buried inside and small vertical fins. At some angles it virtually disappeared from radar, and at no angle did it return an intense echo.

Over the years engineers have come up with an ever clearer idea of why the Bear and Vulcan looked so different to radar—and how they could design a stealth aircraft to take advantage of these principles. For example, the spinning compressor blades of a turbo jet inlet send back radar echoes like a beacon. Sharp edges and abrupt angles tend to act like antennas. So do tall vertical stabilizers. "The more you make something into a smooth blob, the better off you are from a radar point of view," says R. John Hansman, an aeronautical engineer from the Massachusetts Institute of Technology.

But designers of all-out stealth aircraft are concerned with more than just the shape. The materials used in the structure are also selected to help with the job. Carbon fiber materials, for example, are made by embedding thin filaments of carbon in an epoxy resin. The resultant material is as strong as steel but does not reflect most radar waves well. Its carbon-based molecules tend to absorb microwave energy, as food does in a microwave oven. One plane built largely of carbon fiber was the Lear Fan ["Advanced-Design Lear Fan 2100," June '81] which had to carry two radar transponders. That's because if a single transponder failed, the plane was nearly invisible to radar.

Some versions of such materials reportedly have been considered for the B-2, including a carbon-and-fiberglass composite developed for the Hound Dog missile and a black fiber-reinforced graphite skin. Lockheed's stealth fighter is reported to be made of Fibaloy, glass fibers embedded in plastic, made by Dow Chemical.

Special coatings also help suppress radar reflections. The SR-71, for example, is said to be painted with a radar-ablative paint. This does not absorb radiation, but rather conducts it over the surface of the structure, cooling off hot spots that may develop at edges, corners, and other such places. The substance used on the SR-71 is called "iron-ball" paint, apparently because it contains microscopic iron particles to increase conductivity.

Radar-absorbent paint isn't a new idea. Adolf Hitler's Luftwaffe experimented (but not very successfully) with

The B-2 and B-1B might be used together in a scenario such as this: The B-1B comes in at treetop level, becoming visible briefly as it rises above obstructions on its approach to the target. During its approach, it releases an intense barrage of radar jamming. With the ground radar operators thus distracted, the B-2 sneaks in at high altitude, a position from which it can detect mobile targets, move in close, and destroy targets without being observed.

paints to make airplanes invisible to radar in World War II. At the same time, German submarines had their snorkles painted with a similar substance to keep British radar from detecting them when they poked above the surface.

Absorbent coverings first came to public notice in January 1982, when the U.S. Embassy in Tokyo called the TDK company, a well-known manufacturer of electronic equipment, with a strange request. The Embassy wanted to buy one gallon of paint. So strange were the events surrounding the request that it took until August for Japan's Ministry of Trade and Industry to give an OK.

The paint, it turned out, had been developed to stop leaks from microwave ovens. It contained ferrites—iron-containing compounds—and was apparently of interest to U.S. researchers who were trying to design radar-absorptive coatings for planes. Because Japan bans the export of defense-related technology, and the ferrite paint was apparently wanted for the stealth project, the Ministry took the matter under advisement.

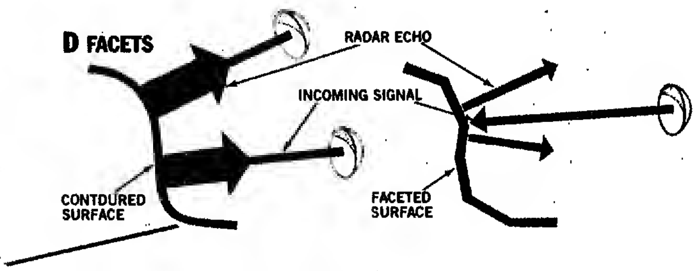
It turned out that another Japanese company—Nippon Electric Co. (NEC) had also developed a similar paint that had been used to coat towers and buildings in sensitive locations to eliminate TV ghosts and scattering of unwanted radio waves. NEC had worked out a technique using two layers of the ferrite material separated by a dielectric—an insulator. Such an electronic sandwich, researchers found, could absorb much of the microwave energy striking it over a frequency range of 3.5 to 20 gigahertz. And, most significantly, most military and commercial radars operate in the 10- to 30-gigahertz range.

That didn't mean the ferrite coating was right for stealth aircraft, however. For one thing, it was too thick and heavy to work properly on aircraft. So work continued.

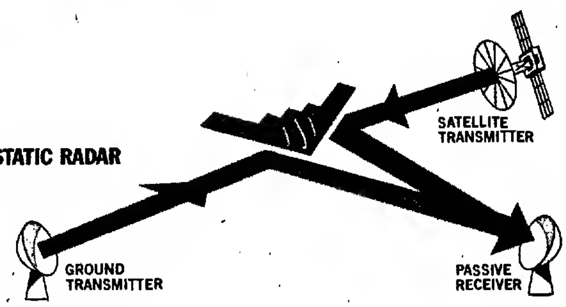
About a year ago a researcher named Robert R. Birge of Syracuse University in New York announced the discovery of a new class of radar-absorbing materials called retinyl Schiff base salts. The salts were black, resembl[illegible] could absorb 80 percent of

in the official release.

D FACETS



E BI-STATIC RADAR



picture was generally right, a defense-industry aircraft designer told the paper that "Many times when we put artist renderings together, we take a great deal of liberty in disguising things we feel are important technologically. And that's what they have done here." A Los Angeles aircraft executive pointed out that important features such as control surfaces had been left out, adding, "I wouldn't bet my grandmother's diamond ring on the accuracy of that picture."

But informed guesses as to the actual plane's details can be made. Everyone agrees that the flying-wing shape is right. That first became reliable news in 1985 when Sen. Barry Goldwater, then chairman of the Senate Armed Services Committee, who had seen a full-scale mock-up of the plane, confirmed that it was a flying wing.

The picture shows that the wings are swept back about 30 degrees, which, as one expert points out, puts the wingtips far enough behind the center of gravity so that you could put effective control surfaces there—surfaces that would operate with moment arms similar to those you get by having a tail at the end of a boom. The pointy nose suggests that there is no dish-shape radar antenna. If the B-2 has a large radar antenna, it more likely is a phased-array radar, in which the antenna is made up not of a single dish, but numerous small elements that could be distributed along the wing.

There is precedence as well. When the original B-1 was modified to its present version—the B-1B—its dish-shape antenna was replaced with a phased array, a modified version of the APG-66 radar developed for the F-16 and used in that fighter for terrain following and general navigation. A yet more advanced version probably appears in the B-2.

The most surprising omission: The drawing shows no control surfaces at all. Some experts guess that there are movable wing surfaces, probably placed as shown in the drawings that accompany this article. Some also speculate that a technique called thrust vectoring—selectively increasing and decreasing thrust to various engines—could help in steering the plane. Or it could use reaction control —squirting jets of high-pressure air through nozzles to change the plane's attitude—a technique used in spacecraft. It might even have wings with inner mechanisms that could actually change shape, with trailing edges bending subtly up or down. This would avoid the radar reflections that can be generated by gaps formed by regular hinged control surfaces.

One expert speculated that the strange sawtooth trailing edge could accomplish two purposes. First, if flaps were mounted in the notches, those flaps would be quite far forward and near the plane's center of gravity. Thus they would not greatly affect attitude or pitch. Second, straight lines tend to reflect radar signals. By breaking the trailing edge up into many lines—no two of them parallel —radar reflections would be minimized. And finally, all agree that the plane undoubtedly uses fly-by-wire techniques. Like the famous wrong-way-wing X-29 [April '80] the flying wing is a fundamentally unstable design. Therefore a computer constantly monitors its actions, rapidly and continuously applying small corrections to keep it flying straight and level.

"I would bet a nice cold beer that it has four engines," said an engineer at a competing aircraft company. The shape of the inlets supports this: The double-scoop design indicates that two pairs of side-by-side engines lurk inside the wing.

The drawing is vague about size. Some experts say the cockpit may be deliberately too large to disguise the true size of the plane. Reasons Bill Sweetman: He has heard that the plane has four GE F-101 turbofan engines—the same power plants used on the B-1B bomber. Each generates 17,000 pounds of thrust, a total of 68,000 pounds. Assuming a standard 0.25 to 0.28 thrust-to-weight ratio for a large four-engine plane, the weight would fall into the 240,000- to 275,000-pound category with a wingspan of 130 to 140 feet. Others have predicted that it would be bigger and heavier. Various reports have guessed that speed would be about Mach 0.8—about the same as an airliner's, and range without refueling some 5,000 miles.

An old idea

The concept of undetectable planes goes back to 1912, when the U.S. Army built a heavily mufflered plane with a carefully camouflaged paint job. The magazine *Aerial Age* noted that the new development "opened up a wonderful field in aviation, making it possible for a biplane or monoplane to sail over cities unheralded and unseen."

Stealth became compelling for military planners in 1973. The Arab-Israeli war broke out, and 40 U.S.-built planes were shot down by Soviet-built SA-6 radar-guided missiles, despite advanced electronic-warfare equipment that was supposed to protect them. Sweetman guesses that by 1975 the Air Force had asked Lockheed's famous "skunk works" run by the legendary Kelly Johnson to produce a stealth aircraft, and that several flying versions—including the apparently now-operational, but not yet public, F-19—have since been flown.

A short time later—probably in 1981—Northrop was tapped to develop what was called the ATB—for advanced technology bomber—which has since come to be called the stealth bomber and lately the B-2. Almost immediately a battle broke out in Congress over whether the country could afford to develop the ATB and also keep developing the B-1—then already underway.

With budget pressures building, the Carter administration canceled the B-1 program, apparently hoping to leap-

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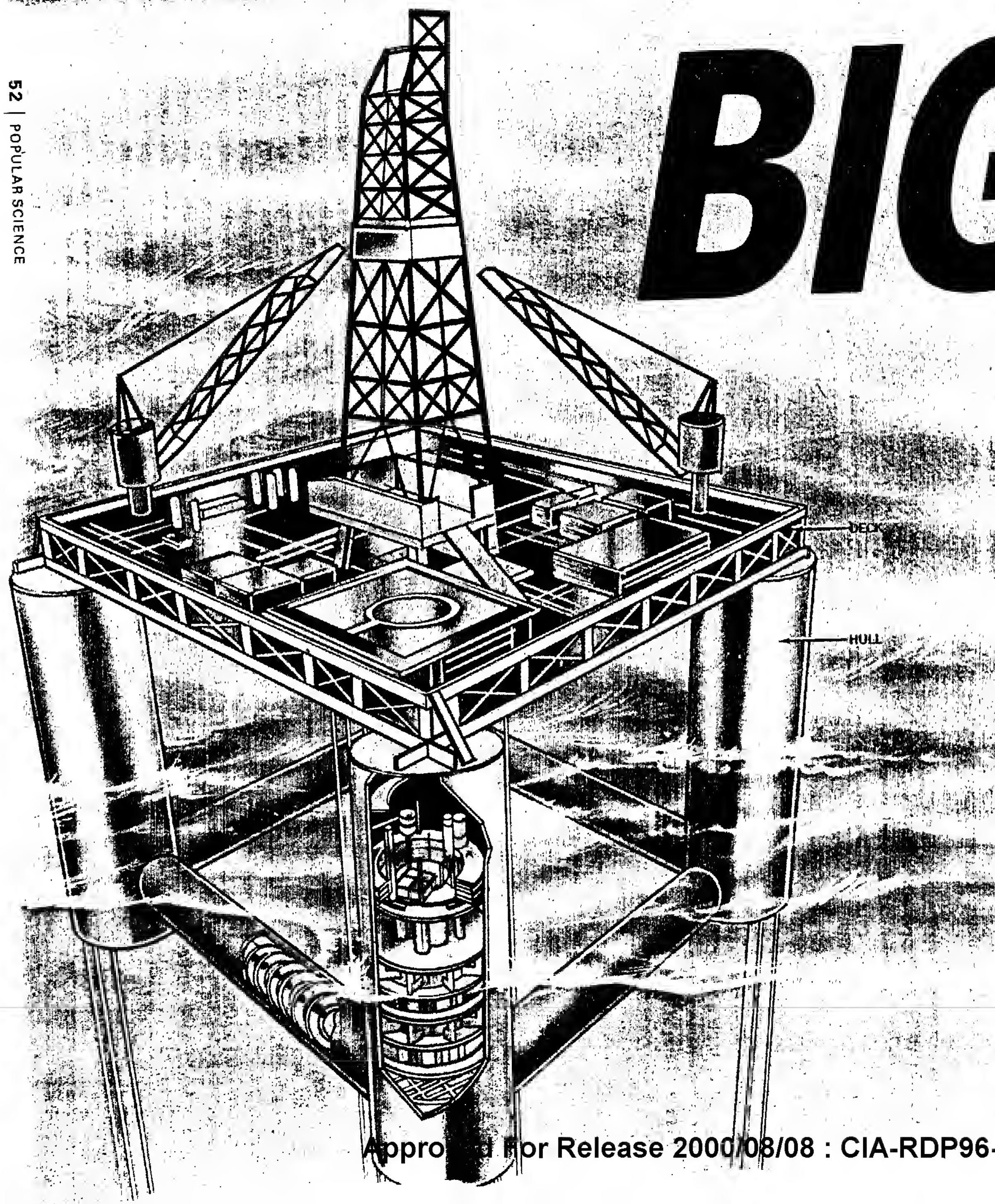
BIG RIG



Anchored 1,760 feet down on the bottom of the Gulf of Mexico, this record-setting tension-leg platform will tap oil from beneath the sea floor. Unlike conventional platforms that sit atop underwater skyscrapers, this newest engineering marvel is anchored by gigantic steel mooring lines.

By NAOMI J. FREUNDLICH
Illustrations by Linda Richards

From a distance the new platform will look just like the others in a growing city of huge underwater skyscrapers that tap the oil-rich seabeds of the Gulf of Mexico. Clustered on the continental shelf, these platforms tap reserves in depths of water of around 1,000 feet. But next year, when tugboats haul Conoco Inc.'s platform into the Gulf, its destination will explain its unusual design. The platform, with its four huge hull columns churning the water, will move past the urban sprawl to new frontiers: the Green Canyon Block 184 oil field, about 170 miles southwest of New Orleans, where water depths reach almost 2,100 feet. When the platform is installed in 1,760 feet, it will be the world's deepest-ever design.

This Gulf of Mexico pioneer is a radically new kind of oil-production platform designed by Conoco to tap deeper reserves economically. Connected to the seabed by 12 tubular steel mooring lines, the platform's natural buoyancy creates an upward force, keeping the legs under tension and allowing it to stay in place in water up to 6,000 feet deep. The tension-leg platform (TLP) is stable and cost effective: It requires far less steel than fixed platforms; and with the help of agile remotely operated vehicles (ROVs), it's easy to maintain. But perhaps the most important aspect of the tension-leg design is its portability. Once a TLP's work is done in one oil field, it can be unhooked from its foundation and moved to another site. Achieving greater depths with the TLP design will require few changes in

Stealth! [*Continued from page 51*]

Such figures show why there has been such a drive to produce stealth airplanes for many years. Some, in fact, hypothesize that more has been spent on stealth than on the much more highly publicized Strategic Defense Initiative, or "Star Wars," project. But while a stealth bomber would have many important advantages, it would have to give up a lot of desirable features as well.

"The more stealthy you make an aircraft, the less efficient will be its performance," says Anibal Tinajero, a defense analyst with the Congressional Research Service. The experts agree: Design a plane for maximum stealth, and you give up performance, range, and payload.

First, stealthy shapes have relatively low inherent stability and controllability. Remember Hansman's remarks about the best stealth shape being a blob? Unfortunately, blobs don't have very efficient aerodynamic shapes. For best directional control and stability, for example, control surfaces are on the tail—well behind the center of gravity. To gain stealth, the B-2 gives up its tail entirely.

While the shape of the Lockheed fighter has never been revealed, it is generally agreed that several have crashed during testing, the last of which was on July 11, 1986, when military authorities cordoned off vast areas of the California mountains in which a plane—never identified—had gone down.

Other threats

Most speculation concerning the B-2 has involved hiding it from enemy radar, because radar is clearly the prime military sensor used today. Yet the plane would be worthless if it could be easily detected and tracked by other methods. For example, satellites with infrared sensors have been highly developed. They're used, among other things, to track-test missile firings by both the United States and the Soviet Union. If stealth put out a hot exhaust trail, it might be tracked by satellite infrared sensors. Three techniques will probably be used by stealth to mask IR. First, the exhaust is apparently below the wing, hidden from direct view by a satellite. Second, it will probably use a broad diffuser that will change the concentrated jet exhaust into a wide thin wedge of gases. And third, a small auxiliary inlet beneath the main engine inlet—engineers call it the boundary-layer gutter—may gather air to mix with the exhaust, cooling it and thus reducing the probability of it being seen by an IR sensor.

Finally, the B-2 will be equipped with the latest electronic countermeasures available. Because it will have such a small RCS, it will be possible to use forms of ECM spoofing not generally available. "Radar cross section is only one aspect that's going to make a super penetrator," said one officer who would not speak for attribution. "The other half is the avionics. When you get the radar visibility down very small, you can start manipulating the radar signals so the enemy doesn't see you."

Such a combination would be able to confuse the enemy even if he picked up a stealth echo. "With a very small target, it's easy to spoof at a low power," says Sweetman. "So you can send back a doctored return. You broadcast something that imitates the return on the first pulse, but then you gradually feed in an error that says you're where you're not. The second pulse is a little bit later than the real pulse would be. The third is still a little more separated, and so on. By this time the radar's logic is locked onto this wrong pulse train, and before you know it, the enemy has got the wrong range."

Although there is no evidence to reveal just where it may stand, there is the possibility of an even more exotic approach. It is a technique called ac-

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